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(56) Documents Cited
GB 2260246 A EP 0366381 A2 EP 0245037 A2
US 4972471 A US 4703476 A

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(54) Inaudible insertion of information into an audio signal

(57) A method of inaudibly inserting information into an audio signal transforms the audio signal (e.g. by FFT) into a succession of frequency spectra over successive relatively long intervals, detects a spectral signal peak above a given threshold for each frequency spectrum, and adds one or more test tones to the masking area of the audio signal adjacent the spectral signal peak, the test tones having a predetermined characteristic relative to the spectral signal peak and representing a reference signal, test signal or data, to produce a transmission audio signal. The transmission audio signal is decoded by converting the transmission audio signal into a succession of frequency spectra over successive relatively long intervals, detecting a spectral signal peak for each frequency spectrum, searching for an associated spectral component (test tone) for each spectral signal peak, and decoding the associated spectral component to recover the data, Fig. 4 (not shown).

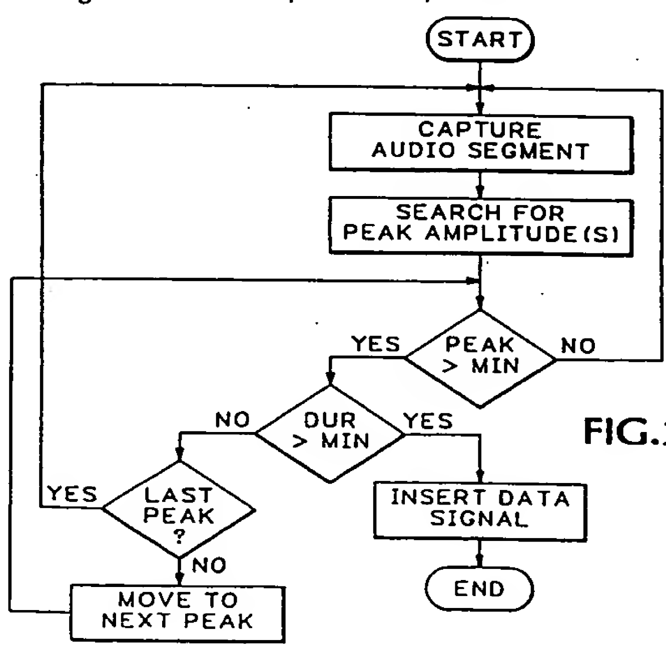

FIG.2

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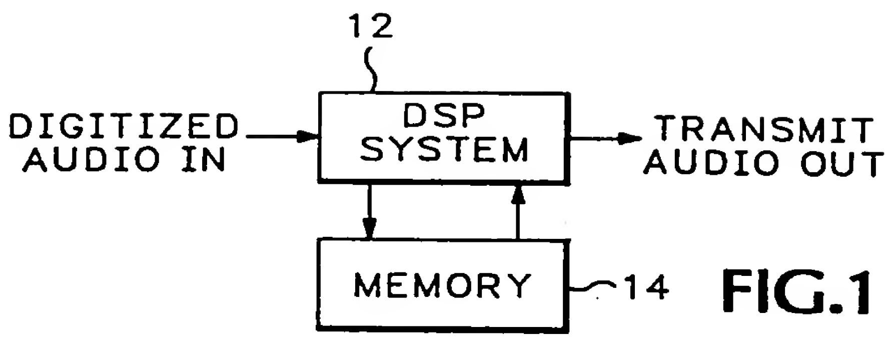
12
DIGITIZED AUDIO IN
DSP SYSTEM
TRANSMIT AUDIO OUT
MEMORY
14

FIG.1

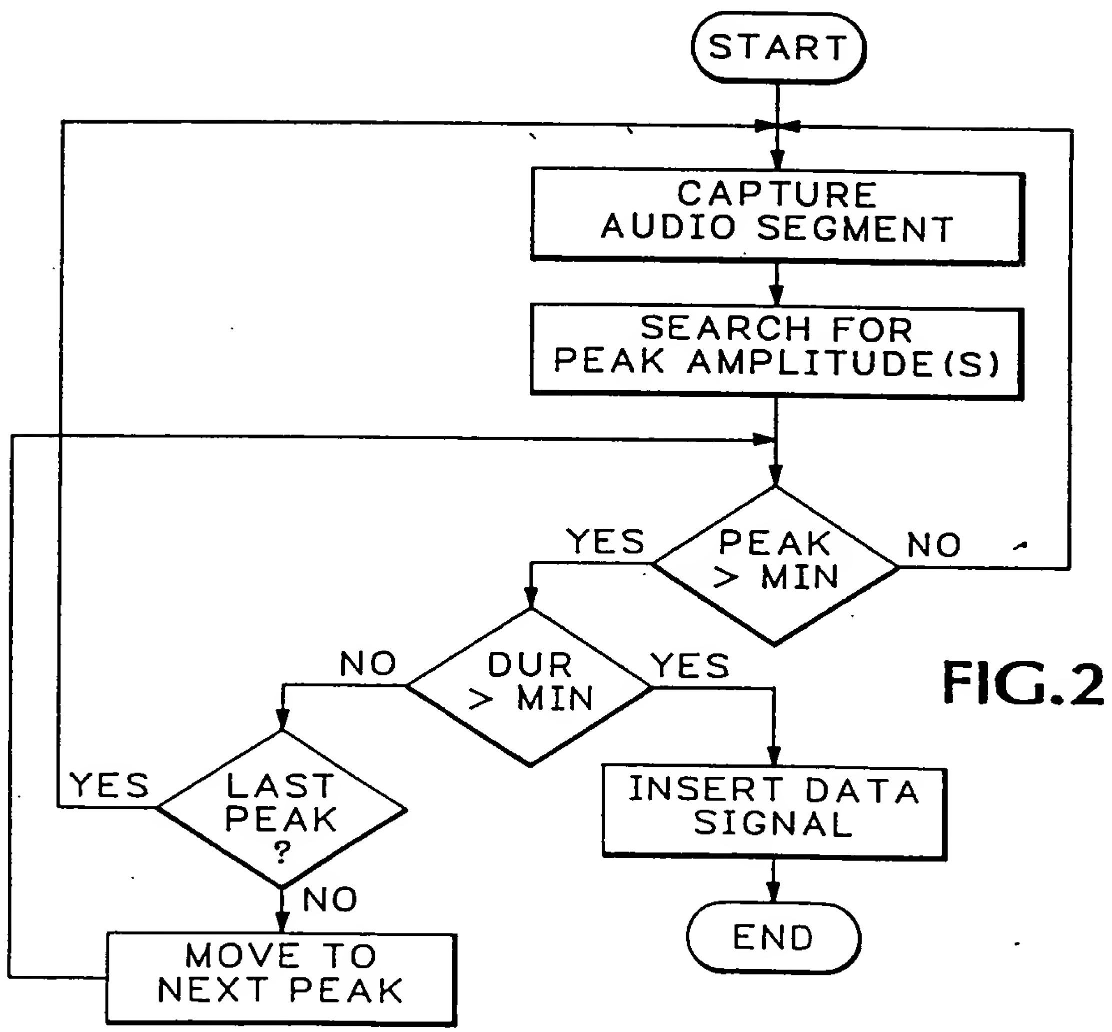
START
CAPTURE AUDIO SEGMENT
SEARCH FOR PEAK AMPLITUDE(S)
PEAK > MIN
YES
NO
DUR > MIN
NO
YES
LAST PEAK ?
YES
NO
INSERT DATA SIGNAL
MOVE TO NEXT PEAK
END

FIG.2

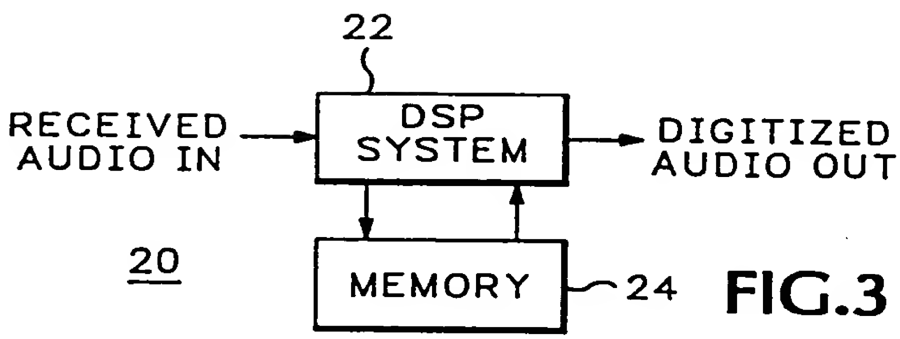
22
RECEIVED AUDIO IN
DSP SYSTEM
DIGITIZED AUDIO OUT
20
MEMORY
24

FIG.3

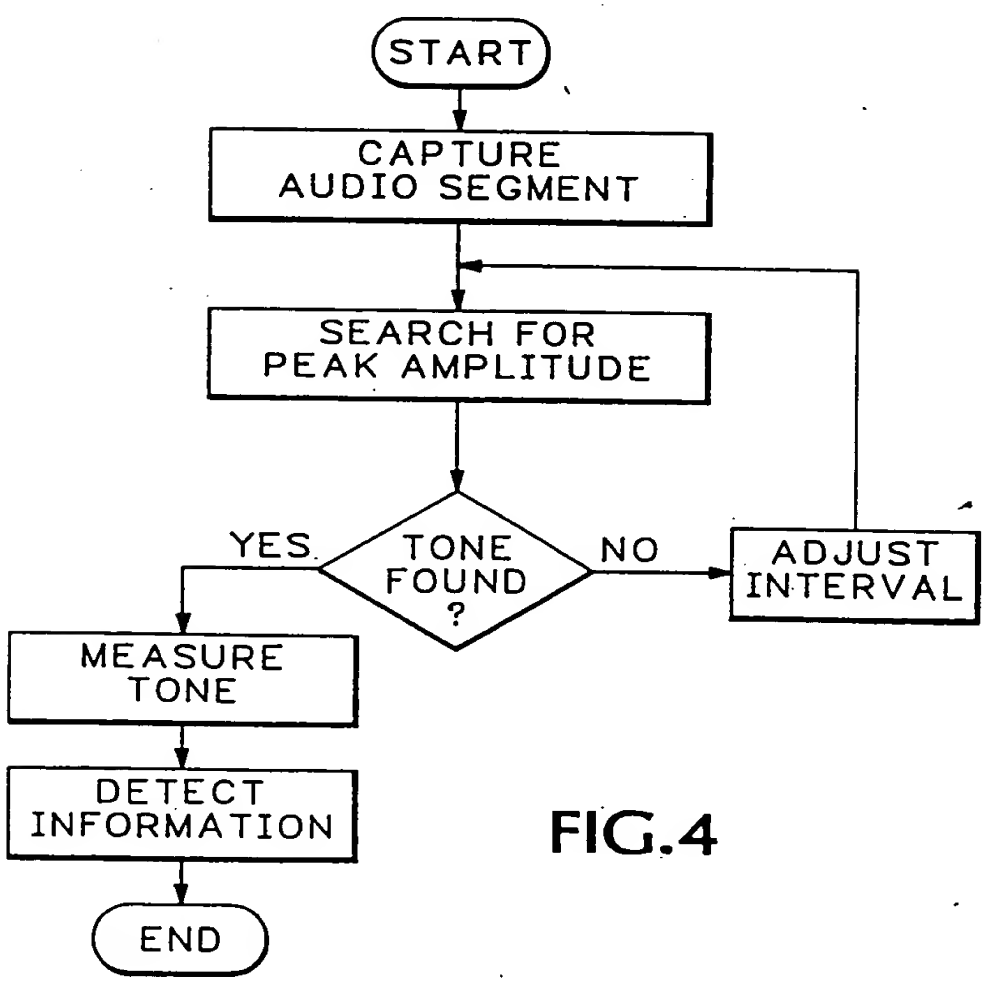
START
CAPTURE AUDIO SEGMENT
SEARCH FOR PEAK AMPLITUDE
YES
TONE FOUND ?
NO
ADJUST INTERVAL
MEASURE TONE
DETECT INFORMATION
END

FIG.4

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INAUDIBLE INSERTION OF INFORMATION INTO AN AUDIO SIGNAL

Background of the Invention

The present invention relates to signal insertion, and more particularly to inaudible insertion of information into an audio signal so that it is inaudible to humans while being recoverable by a receiving system.

The phenomenon of auditory masking in humans is well known and discussed in an article by Eberhard Zwicker and U. Tilmann Zwicker in the Journal of Audio Engineering Society, Vol. 39, No. 3, March 1991 entitled "Audio Engineering and Psychoacoustics: Matching Signals to the Final Receiver, the Human Auditory System", incorporated herein by reference. This effect is a current technology being exploited in audio signal compression by removing parts of the audio signal that humans cannot hear, thereby reducing the amount of information being transmitted.

In many instances it is desirable to insert a signal representing some information that a receiver may want to use, such as a test signal, a reference signal or data, into another information signal. An example is the insertion of a vertical interval test signal (VITS) into the vertical interval of a television video signal. VITS is inserted into a portion of the television video signal that is not displayed to a viewer, so it is transparent to the viewer. However it is not apparent how an information signal could be inserted into an audio signal since there are no "non-

visible" areas in the audio signal corresponding to the retrace intervals of the television video signal.

What is desired is the insertion of an information signal into an audio signal in a manner that is inaudible to a human.

Summary of the Invention

Accordingly the present invention provides for inaudible audio signal insertion of an information signal into an audio signal by inserting the information signal into audio masking regions of the audio signal. The information signal is encoded via tones inserted into the audio masking regions. The encoding may be by the presence or absence of an inserted tone or tones, the amplitude of the inserted tone or tones, the phase of the inserted tone or tones, or any combination of these encoding techniques. At a receiver the inserted tone or tones, or presence or absence of the tone or tones, is decoded to recover the original information signal.

The objects, advantages and other novel features of the present invention are apparent from the following detailed description when read in conjunction with the appended claims and attached drawing.

Brief Description of the Drawing

Fig. 1 is a block diagram of an encoder for inaudible audio signal insertion according to the present invention.

Fig. 2 is a flow chart diagram of a method of inserting information

into an audio signal according to the present invention.

Fig. 3 is a block diagram of a decoder for inaudible audio signal insertion according to the present invention.

Fig. 4 is a flow chart diagram of a method of extracting information from an audio signal according to the present invention.

Description of the Preferred Embodiment

Referring now to Figs. 1 and 2 an audio signal, suitably digitized, is input to a digital signal processor (DSP) 12, and also stored in a memory structure 14 configured as a delay element. The DSP 12 performs a frequency domain transformation, such as a fast Fourier transform (FFT), on the digitized audio signal repetitively over a relatively long interval of the audio signal, such as milliseconds up to one second or more depending upon the particular application, converting the audio signal from the time domain to the frequency domain. For example for speech applications the interval may be long, while for music the interval may be short, so long as the interval is long enough to trap a relatively large peak while not getting too many peaks.

The output from the frequency domain transformation is a succession of frequency spectra. Over the interval the largest amplitude spectral component for the associated frequency spectrum is searched for to determine the signal peak. The signal peak is compared with a minimum threshold level, such as -18 dB. The minimum threshold is

calculated based upon the amplitude of the inserted signal, the inserted signal recovery technique, and the signal to noise (S/N) ratio required at the receiver for the inserted signal. The minimum threshold may be precalculated for a given application and stored in the DSP 12. If the signal peak is less than the minimum threshold level, then the next interval is processed to obtain a new frequency spectrum. If the signal peak is above the minimum threshold and of sufficient duration, a tone is inserted into the audio signal in a masking area around the signal peak. The frequency and amplitude of the tone are based on the masking characteristics of the signal peak. The duration and shape of the tone are designed to maximize the energy in the test tone and minimize the energy not at the test tone frequency. For example, if the test tone is at a frequency ten percent (10%) higher than the signal peak, the shape of the test pulse is a sine-squared bar, the 100% amplitude duration is exactly three cycles of the test tone, and the amplitude of the test pulse is set to -40 dB, then if the duration of the signal peak is less than that calculated for the test tone, the test tone is not inserted and the algorithm is started again over the next interval.

As shown in Figs. 2 and 4 the input to a decoder 20 is the encoded audio signal in digital form, which signal may have undergone several processes that have changed the level of the entire signal. The encoded audio signal is input to a decode DSP 22 where again a frequency domain transformation is performed repetitively over a long interval of the input

signal corresponding to that used at the transmitter, giving successive frequency spectra. Again the largest amplitude spectral component in the interval is searched for, the signal peak. For the frequency of the signal peak an associated spectral component is searched for that was inserted by the transmitter, i.e., a spectral component with the correct frequency offset and pulse width. For reliability the process may be repeated over successive intervals to assure that the expected pulse is found successfully a few times in succession. For repeating over several intervals the audio interval(s) may be stored in a random access memory 24 when the DSP 22 is not fast enough. If the inserted pulse is not found, which is possible since the largest signal peak may not be the same one the encoder found due to differences in timing between the encoder and decoder, the decoder slides the interval window along in time until the signal peak found by the encoder is also found by the decoder. Once this synchronization of decoder with encoder is completed, then decoding occurs continuously. The detected pulse is then measured for amplitude, phase, etc. and, for example, the overall input signal is adjusted to the correct level based on the measured amplitude of the test pulse for an automatic gain control (AGC) application, or the detected pulse is otherwise decoded for its information content. For example in an AGC application if the pulse is detected at -32 dB, this means that the signal level needs to be reduced by 8 dB since the transmitted pulse in this example was inserted at -40 dB. The decoder may also remove the transmitted test pulse from the output

signal if desired. Of course most audio compression techniques based on masking will remove the transmitted test pulse.

Thus the present invention provides for insertion of inaudible audio signals into an audio signal at a transmitter by inserting defined audio tones in masking regions of the audio signal, and then extracting the defined audio tones at a receiver, which extracted audio tones are decoded.

WHAT IS CLAIMED IS:

1. A method of inserting inaudible audio signals into an audio signal comprising the steps of:

repetitively performing a frequency domain transformation on the audio signal over successive intervals of a first predetermined duration to produce successive frequency spectra;

finding the largest amplitude spectral component within each frequency spectrum to determine a transmission signal peak;

for each transmission signal peak above a given threshold adding a test tone into the audio signal with predetermined characteristics relative to the transmission signal peak, the test tone representing data, to produce a transmission audio signal.

2. The method as recited in claim 1 further comprising the steps of:

performing the frequency domain transformation on the transmission audio signal over successive intervals of a second predetermined duration to produce frequency spectra;

searching each frequency spectrum for a received signal peak;

for each received signal peak searching for the test tone;

sliding the successive intervals of the second predetermined duration in time and repeating the searching steps until the test tone is detected; and

decoding the test tone to recover the data represented by the test tone.

3. The method as recited in claim 1 further comprising the steps of:

performing the frequency domain transformation on the transmission audio signal over successive intervals of the first predetermined duration to produce frequency spectra;

searching each frequency spectrum for a received signal peak;

for each received signal peak searching for the test tone; and

decoding the test tone to recover the data represented by the test tone.

4. A method of inserting inaudible audio signals into an audio signal substantially as herein described with reference to and as shown in the accompanying drawings.

The Patent Office

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Application No: GB 9521951.5
Claims searched: 1-4

Examiner: Keith Williams
Date of search: 15 December 1995

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.N): H4P (PDX,PEUM,PEUX); H4R (RPX,RSEX,RSX)

Int Cl (Ed.6): H04H 1/00, 9/00; H04S 7/00

Other: online WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2260246 A	The Arbitron Co. - see Claims 1,3 and Fig.1 (equivalent to WO 93/07689)	1,3
A	EP 0366381 A2	Thorn EMI - see column 4, lines 15-22 (equivalent to US 5113437)	1
A	EP 0245037 A2	Thorn EMI - see page 12, lines 19-23 (equivalent to US 4876617)	1
A	US 4972471	Gross et al. - see column 3, lines 1-23 (equivalent to WO 92/05550)	1
A	US 4703476	Audicom Corp. - see abstract (equivalent to EP 0135192)	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		